Closing the Feedback Loop: A 12-month Evaluation of ASTA, a Self-Tracking Application for ASHAs

Brian DeRenzi[†] Jeremy Wacksman[ϕ] Nicola Dell[‡] Scott Lee[Ψ]
Neal Lesh[ϕ] Gaetano Borriello[λ] Andrew Ellner[Ψ]

[†]University of Cape Town
bderenzi
@cs.uct.ac.za

[ϕ]Dimagi, Inc.
jwacksman,nlesh
@dimagi.com

[‡]Cornell Tech
nixdell
@cornell.edu

[Ψ]Harvard University
slee@hbs.edu
aellner@partners.org

[λ]University of Washington
gaetano
@cs.washington.edu

ABSTRACT

Accredited Social Health Activists (ASHAs) have been shown to have a positive impact on health outcomes of the households they visit, particularly in maternal and neonatal health. As the first line of the public health system in many countries, they are a critical link to the broader public health infrastructure for community members. Yet they do this all with minimal training and limited support infrastructure. To a pregnant woman, an ASHA is a trusted ally in navigating the health system—information gathered is returned by appropriate advice and counseling. To the health system, the ASHA is a key channel of valuable household-level information for the public health system, yet she generally receives minimal guidance in return. In this paper we present ASTA—the ASHA Self-Tracking Application—a system that provides ASHAs with timely, on-demand information regarding their own performance compared to their peers. Using ASTA, ASHAs access comparative performance data through both a web-based and voice-based interface on demand. We evaluated ASTA through a 12-month deployment with 142 ASHAs in Uttar Pradesh, India, assessing the impact of providing feedback on ASHA performance. We find that ASHAs with access to the ASTA system made significantly more client visits, with average monthly visits 21.5% higher than ASHAs who had access to a control system. In addition, higher ASHA performance was correlated with increased usage of ASTA. However, the performance improvement was front-loaded, with the impact of the system decreasing toward the end of the study period. Taken together, our findings provide promising evidence that studying and incorporating tools like ASTA could be cost effective and impactful for ASHA programs.

CCS Concepts

•Human-centered computing → Human computer interaction (HCI);

ICTD '16, June 03 - 06, 2016, Ann Arbor, MI, USA

ISBN 978-1-4503-4306-0/16/06…$15.00

DOI: http://dx.doi.org/10.1145/2909609.2909652

Keywords

ICTD; HCI4D; ICT4CHW; mHealth

1. INTRODUCTION

Community Health Workers (CHWs) are often critical change agents for the health of populations in low-income settings. They are recruited from and deeply embedded in the communities where they work, provide appropriate counseling and referrals during home visits, and serve as a critical link between communities and the public health system. Research has demonstrated repeatedly that CHWs can play a role in improving health indicators of their target populations in well-run community health programs. In Ethiopia, mortality rates for children under five years old were reduced by 40% when mothers received counseling from a CHW on how to recognize and respond to malaria symptoms [17]. A study in Bangladesh demonstrated that an intervention where CHWs played a critical role in reaching new mothers could reduce neonatal mortality rates by 34% [5]. Finally, in Uttar Pradesh, India, an intervention using CHWs to counsel on healthy pregnancies and newborn care led to a 54% reduction of newborn deaths [19].

To effectively manage and evaluate CHW interventions and applications, many programs require that CHWs collect and report data about the initiatives in which they are engaged. Increasingly, this information is being collected by CHWs using mobile devices, including through SMS-based reporting tools [6, 21], text-based applications [9, 14], or voice-based IVR systems [33]. To date, the vast majority of these data collection efforts have focused on one-way communication of information from the CHW to a database accessible only to health system administrators and supervisors. As a result, although higher-level supervisors, ministry officials, and NGO employees may see and make use of collected data, the CHWs themselves rarely receive timely feedback on their performance or confirmation that the data they are collecting is being used.

We conjecture that "closing the feedback loop" will improve the performance of CHWs. In this paper, we investigate this conjecture by building, deploying, and evaluating a system that makes comparative performance data available on demand for CHWs. We worked with Accredited Social Health Activists (ASHAs), the largest cohort of CHWs in India, to develop the ASHA Self-Tracking Application (ASTA). ASTA is a mobile system that provides performance feedback to ASHAs through two interactive systems

that run in parallel: a web-based system and a voice-based system. The web-based system is comprised of a set of three visualizations. The first allows ASHAs to see, using a simple histogram, how many visits they have completed during the current calendar month compared to a subset of their peers. It also provides an indication of their progress towards their monthly goal of visiting all their pregnant clients. The second visualization shows the ASHAs the number of visits that they made each day of the current month. The third visualization shows the total number of clients visited in the current month along with the previous five months, providing a sense of historical context. The parallel voice-based system provides the same information as the histogram page over a mobile phone line, telling an ASHA how many of her clients she has visited out of the total number she has registered, as well as her current rank relative to a subset of her peers. ASHAs are able to access either or both the web-based and the voice-based systems whenever they choose.

To assess the impact of ASTA on ASHA performance, we conducted a 12-month randomized experiment with 142 ASHAs in the Kaushambi district of Uttar Pradesh, India. We compared the number of monthly client visits performed by two groups of ASHAs: a *treatment* group that had access to voice- and web-based performance data through ASTA and a *control* group who had access to a similarly structured, but non-personalized, basic information service. Findings from our deployment show that ASHAs with access to ASTA made significantly more client visits, with average monthly visits 21.5% higher than those in the control group. In addition, we found that higher ASHA performance was correlated with higher usage of the system. However, the improvement in ASHA performance was front loaded, with a decreased impact by the end of the 12-month deployment. Taken together, our findings show that providing ASHAs with feedback has the potential to positively impact their performance, although more work is necessary to understand how these benefits may be sustained in the long term.

2. BACKGROUND AND RELATED WORK

Many CHW programs across the world aim to magnify the reach of over-stretched health systems in resource-constrained environments by providing community members with access to health services through local, community affiliated CHWs [34]. This is important because patients often delay seeking care, even in cases severe illness [37], and scheduled visits have been shown to be part of effective interventions [5]. Prior research has shown that using CHWs as part of a comprehensive public health delivery strategy can positively change behavior and significantly lower mortality rates [5, 19, 31], particularly for maternal and newborn health.

However, research has also shown that effective CHW programs are challenging to run and maintain [20, 30]. For example, supportive supervision is needed to diminish feelings of isolation among CHWs, while infrastructure and logistical support, such as reliable transport and equipment supplies, also impact the effectiveness of CHW programs [20, 28]. To overcome some of these challenges, researchers have been increasingly turning to the use of mobile devices to support CHW programs. For example, mobile phones have been utilized to increase efficacy [26], adhere to visit protocols [12, 10], or send reminder messages to CHWs or patients [4, 8, 9]. In addition to supporting CHWs with their work, mobile devices have also been utilized extensively to facilitate the collection of patient data by CHWs [6, 7, 14]. The collected data is typically made available to CHW supervisors along with various partner, donor, and government organizations to enable monitoring the health of populations and the impact of interventions. However, to date, the data collected by CHWs has usually not been made available to the CHWs themselves. Our work aims to close this feedback loop by providing CHWs with timely, on-demand information and visualizations regarding their own performance that is derived from data they collect. To the best of our knowledge, ours is the first intervention that provides CHWs in ICTD contexts with personalized, real-time performance feedback.

There have been numerous efforts in the health domain to improve the performance of medical workers (*e.g.*, [23, 38]). In addition, work in human-computer interaction has looked specifically at how mobile devices can be used for healthcare delivery [18]. Fogg has also written extensively on behavior change through technology use, including focusing on how persuasive technologies may be used in health contexts [13]. Several projects have also focused specifically on CHWs in ICTD contexts. For example, DeRenzi et al. looked at if CHW performance could be improved through the use of an automated SMS system that would escalate up to supervisors after a short period [9]. Although this system worked effectively to amplify the supervisor's intentions, when the supervisor was removed from the loop the performance of the CHWs decreased. Our work differs in that, rather than involving the supervisor, our system is targeted solely at the CHWs and aims to amplify their intentions of doing work by providing the ability to track their own performance.

Finally, since many of the ASHAs in our research are low-literate, our work draws heavily on related research that focuses on designing technologies and interfaces for low-literate populations. Both voice-based systems [24, 25, 29, 33] and graphical systems [22] have been used to support low-literate and novice users in ICTD contexts. Our work builds on this existing research by providing *both* graphical and voice-based systems to support CHWs. Instead of adopting a single interaction modality, we instead provide participants with both a web-based and a voice-based system, with the goal of allowing CHWs to use either or both interaction methods whenever they choose.

3. ASTA SYSTEM DESIGN

The goal of our work is to investigate the impact of closing the feedback loop by providing ASHAs with on-demand data regarding the work they have done. This section describes the context in which our research was conducted, our design methodology, and the details of the different ASTA system components that we developed.

3.1 Research Context

In the context of our research, ASHAs are married women who provide health counseling and limited medical services to the communities in which they live. They receive basic training on a number of health topics with an emphasis on maternal, newborn, and child health. They generally work closely with an Antenatal Nurse Midwife (ANM) and an ASHA Facilitator who serves as the ASHA's supervisor. Although ASHAs have a wide range of responsibilities, in practice they are primarily focused on child immunizations and maternal health. In this study the focus is on antenatal care, for which ASHAs are encouraged to identify pregnan-

cies, make regular monthly visits to the homes of pregnant women, provide counseling on relevant health topics, and make referrals to health services for antenatal checkups and care of complications. Although ASHAs do not receive a salary, they do receive financial incentives when their clients take certain actions, such as a child completing their full set of immunizations or a woman giving birth in a facility [15].

We conducted our study in Uttar Pradesh, India. Uttar Pradesh is the most populous state in India with 200 million residents. It also has some of the country's worst performance on many maternal, newborn, and child health indicators. For example, in the 2011 census [2] the maternal mortality rate in Uttar Pradesh was 392 deaths per 100,000 live births, compared to the national rate of 178, and the infant mortality rate was 50 deaths per 1,000 live births, compared to the national rate of 40. Uttar Pradesh also faces a range of social issues, including 30% illiteracy and a sex ratio of 908 women to 1,000 men. Health infrastructure is lacking, with massive shortages of functional health subcenters, primary healthcare centers, and health workers [1].

The ASHAs at our study site were participating in an ongoing mobile health program called Reducing Maternal and Newborn Deaths (ReMiND) [3]. Catholic Relief Services (CRS), a large international NGO, supports the program through its local implementing partner, Vatasalya. ASHAs participating in the existing project had previously received Nokia C-2 feature phones running a CommCare [11] application to guide their work and aid data collection. For example, a checklist in the app guides ASHAs through algorithms specific to the phase of a client's pregnancy to identify possible danger signs and encourage preparation for birth. Another form provides images and audio messaging around key antenatal care topics. The ASHAs had previously received intensive training on CommCare and were actively using it when visiting pregnant clients in their communities. As part of the existing project, ASHAs were visited frequently by field staff members from Vatsalya who would observe home visits, suggest best work practices, offer assistance with CommCare, and help those who were struggling with their responsibilities. ASHAs were responsible for maintaining the phones and were allowed to use them as personal devices as long as they added credit for their own use and did not delete CommCare. Feature phones were selected because they were available locally, familiar to many users, affordable, physically rugged, and had favorable battery life.

3.2 Providing Feedback to ASHAs

We chose to provide ASHAs with feedback through metrics that would incentivize an increase in home visits to pregnant women. Since the key metric for ReMiND is the number of pregnant clients that an ASHA visits each month, we chose this metric for our study as well. We did not use the percentage of clients visited as this would have created an incentive for ASHAs to register fewer pregnant women to boost their scores. By contrast, using the total number of client visits as the performance metric encourages an ASHA to register more pregnant women to achieve a higher score.

To calculate the number of clients that an ASHA visited, we use the set of CommCare home visit form submissions for the ASHA and count the number of unique women visited each day. Multiple forms about a single client only count as a single visit for the day. We pull this data from the CommCareHQ server nightly and use it to update the web- and voice-based ASTA systems.

3.3 The Web-Based System

The ASTA web-based system was developed over a two-month period using an iterative participatory design process. Initially we intended to have a single visualization to show the ASHA how much work she had completed during the month. However, we later expanded the number of visualizations from one to three because we received a positive response to several different designs.

The iterative process began with a designer creating an initial mock-up that was taken to the field for testing. The team spent the first two weeks in India visiting a variety of different organizations using CommCare to support ASHAs, showing the ASHAs potential visualizations and capturing a wide range of feedback. These feedback sessions constituted an essential component of our design process as we experimented with both the digital mock-ups , as well as a variety of potential visualization mock-ups on paper that incorporated ideas we received from ASHAs in the field.

After obtaining feedback from ASHAs during the initial two weeks, we focused our rapid iterative design and prototyping on the research site with the ReMiND program. We worked intensely with five ASHAs from an adjacent block who had helped to design the ReMiND CommCare application. This allowed us to work with representative ASHAs without pre-exposing our study participants. After each design session, we collected feedback and updated our designs before the next session. After over 20 mock-ups we arrived at the final set of three graphical visualizations that constitute the ASTA web-based system.

ASTA requires the ASHA to have an active Internet connection and is designed to work with the Nokia C-2 feature phones that the ASHAs in the ReMiND project are already using. Visualizations are generated daily as a web page rendered as a high-quality PNG file using PhantomJS[1] to ensure consistent display. For each ASHA, a url linking to a unique web page for the ASHA was saved as the browser's only bookmark. All ASHAs had at least periodic access to a data connection, which was required to submit CommCare data for ReMiND, and were provided with monthly data bundles for their normal work that we did not supplement.

The final set of web-based graphs used in ASTA can be seen in Figure 1. The system consisted of four main pages that ASHAs accessed on demand. The *landing page* is the first page an ASHA sees each time she opens the ASTA system and allows her to navigate among the other pages. The *progress page* provides a snapshot of progress visiting clients, as well as the ASHA's standing relative to a subset of her peers. On the *calendar page* ASHAs see the number of client visits on each day in the current month. Finally, the *history page* provides a five month historical view of the number of clients visited per month.

The set of peers on the progress page was selected randomly each month. It was randomized to ensure no ASHA is stuck with a set of high- or low-performing peers and is held consistent to allow ASHAs to view progress.

3.4 The Voice-Based System

The baseline survey revealed that approximately 30% of the ASHAs are low-literate. As a result, we developed a

[1]http://phantomjs.org/

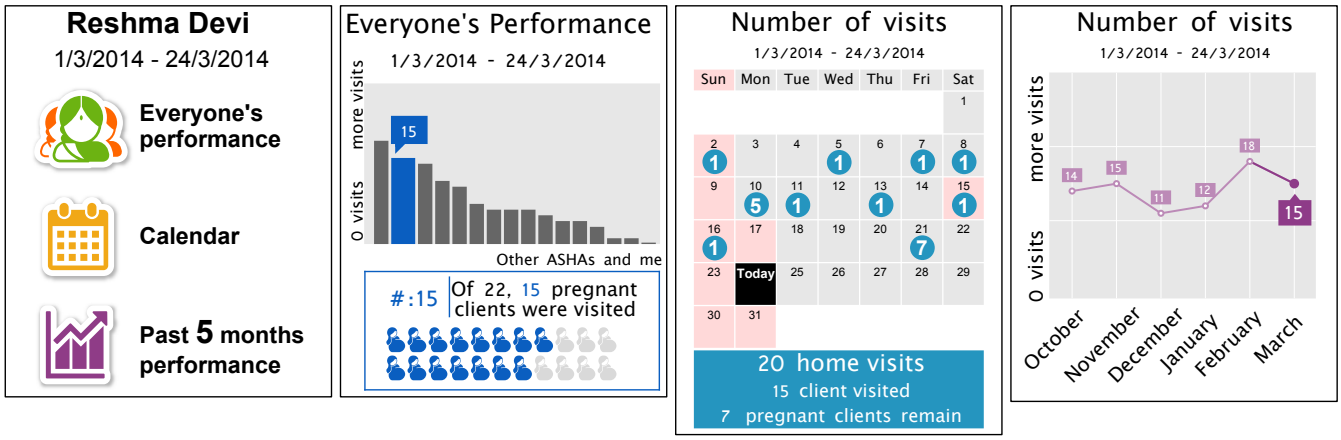

Figure 1: Screenshots from the ASTA web system. Although we show the text in English here for readability the deployed application was completely in Hindi.

parallel voice-based system to provide an alternate interaction modality that would be more appropriate for low-literate ASHAs. Our voice-based system replicates only the information provided by the progress page as verbalizing the other visualizations would have required ASHAs to listen to long, confusing recordings. Audio templates were recorded in Hindi by a local staff member and dynamically stiched together to provide performance information. A typical recording would read:

> *"Hello Sunita Devi. During May you have completed five home visits and seven more remain. Among 12 ASHAs you are in the third position."*

The voice-based system is hosted by Awaaz.De[2], a local provider of voice services. To access the ASTA voice service, an ASHA makes a missed call to an Awaaz.De number saved in her phone. The system calls the ASHA back and reads her performance details if the number was recognized, or, if not, instructs the caller to use her CommCare phone.

3.5 The Control Systems

To isolate the effects of providing performance feedback to ASHAs, we also created alternate "control" versions of both the web- and voice-based systems that provide generic encouragement to ASHAs without personalized feedback. The control version of the web-based system can be seen in Figure 2. Mimicking the ASTA system, the control system also has four sections. The *landing page* has the same structure as the ASTA system, but links to non-personalized content. The *responsibilities of an ASHA* page contains tips about being an effective ASHA. *Advice for pregnant women* contains information to share with clients to ensure a healthy and safe pregnancy. Finally, there is an *inspiring quote*.

The control version of the voice-based system provided a voice representation of the web data. In this case all three sections were read to the user as all were straightforward to verbalize. They were presented in the same order as the web system: the responsibilities of an ASHA, advice for clients, and the inspiring quote. The content of the control system was updated daily, drawing randomly from a collection of 52 sets of generic encouragement.

[2]https://www.awaaz.de/

For the control and ASTA systems, both the web- and voice-based systems were accessible on demand. Additionally, both were piloted in the adjacent block (where the design work took place) to ensure stability and completeness before deployment. We also used this pilot period to develop and test relevant training materials and coordinate additional deployment logistics.

4. EVALUATION

The goal of our work was to understand if, and how, giving ASHAs access to feedback regarding their work impacted their overall performance. To achieve this goal, we conducted a 12-month mixed methods study that compared the performance of ASHAs that had access to the ASTA system with those that had access to the control system. IRB approval for the study was obtained from Harvard University, the University of Washington, and a local Indian university, Maulana Azad Medical College. The rest of this section describes our main research questions, the characteristics of our participants, and our study methodology.

4.1 Research questions

To learn how the ASTA system affected overall ASHA performance, we formalized our study into the following three research questions:

Q1: How did access to performance feedback affect the number of clients an ASHA visits?
We hypothesized that ASHAs who were given access to feedback through ASTA would perform better than ASHAs who had access to the control system.

Q2: How did ASHA performance change over the 12 month deployment period?
Our deployment lasted for 12 months, which is a relatively long period of time for an initial evaluation of an ICT4D intervention. As a result, we were interested to analyze how ASHA performance in each group changed over time. In particular, prior work has shown that sustained ASHA engagement requires regular monitoring and supervision of ASHAs [9]. Since we did not provide such supervision, we wanted to see if ASHA engagement with the system declined.

Figure 2: Screen shots from the control application. Although we show the text in English here for readability the deployed application was completely in Hindi.

Q3: Is there a correlation between the amount of ASTA usage and ASHA performance?
Since ASHAs were able to access the system on demand, we were interested to see if there was a correlation between ASHA performance and how much they accessed the system.

4.2 Participants

All ASHAs involved in the ReMiND project at the research site were invited to participate in our study. Although we initially recruited 146 participants, four did not complete the study because they either stopped working as an ASHA or moved away from the area. As a result, our final sample included 142 ASHAs: 71 in the control group and 71 in the treatment group. All participants were female and ranged in age from 21 to 55 years ($M = 33$ years, $\sigma = 7$). Officially a woman must be married to be an ASHA, though at the time of recruitment, 6% ($n = 8$) were either divorced or widowed. Household sizes ranged from 1 to 19, with a median size of 6 ($\sigma = 3.1$). Most ASHAs were involved with agriculture (67%; n = 95), livestock rearing (72%; $n = 102$), or a non-agricultural family business (11%; $n = 16$).

The ASHAs generally had low levels of education, with 42% having completed grade 10 and 3.5% reporting no formal schooling. In addition, almost 30% ($n = 42$) were unable to easily read a basic Hindi sentence. The ASHAs came from a range of socioeconomic backgrounds. 43% ($n = 61$) had access to electricity at home and 53% ($n = 76$) used a public hand pump for water. 58% of ASHAs ($n = 83$) were from families that owned at least some land and almost all (94%; $n = 134$) had access to a mobile phone in their household other than their work phone.

When asked about their motivations for being an ASHA, participants reported a wide range of reasons for pursuing their jobs. The most common motivating factors were prospects for a future career, serving their community, and gaining respect from their community.

4.3 Procedure

After we recuited participants and obtained informed consent, we randomized participants into control and treatment groups using stratified randomization that ensured balanced groups by taking into account key demographic characteristics, such as literacy, socioeconomic status, and technical knowledge. All participants began by completing an intensive baseline interview to collect demographic characteristics, socioeconomic status, health knowledge, experience with technology, social and community networks, and prior work experience. All interviews were conducted by local research staff in Hindi with data collected electronically before being analyzed using Stata.

After the baseline interview, ASHAs were trained to use either the ASTA or control system during a two hour, in-person session. The ASTA training covered basic information about interpreting general graphs before building up to the actual ASTA visualizations. After completing their training, participants were free to access both the web-based and voice-based systems as often as they chose. In addition, a weekly SMS message was sent out to remind participants to check the ASTA or control system by either opening their link or calling into the voice-based system.

As part of ReMiND, Vatsalya staff maintain phones and ensure sufficient Internet balance so ASHAs are able submit data via the CommCare application and use the ASTA web-based system. Project staff were instructed to direct all questions and issues with ASTA to the research team in order to maintain a distinction between the research project and normal ReMiND operations. Throughout the study a full-time research assistant was available to provide support when technical issues arose and to address any confusion with ASTA. The ASHAs were all able to directly contact the research assistant at any time.

Finally, at the end of the study period we conducted semi-structured qualitative interviews with 19 participants to gather more detail about their experience with and usage of ASTA. We chose a diverse subset of ASHAs by including participants with varying literacy levels and system usage to create a sample representative of the diversity of the entire cohort. Participants were asked about their perception of and reaction to ASTA, preferences between the voice-based and web-based systems, any confusion that they felt interpreting the data, and their system usage habits. Interviews were conducted by the local research assistant in Hindi and responses translated into English for further analysis.

5. DATA ANALYSIS AND RESULTS

We analyze the impact of the ASTA system through a number of outcome metrics that capture ASHA performance

and system usage behavior. Our primary metric is the number of client visits an ASHA makes in a given calendar month, with more visits constituting higher performance.

Our analyses capture the change in ASHA performance between a 12-month *baseline* period where ASHAs used the ReMiND CommCare application before ASTA and a 12-month *intervention* period after the system was deployed.

To assess system usage and understand how ASHAs used each of the voice- and web-based systems we logged system access. For the web-based system, we recorded a timestamp and the specific visualization(s) accessed. For the voice-based system, we recorded a timestamp, the length of the phone call, and how much of the recording the ASHA listened to before disconnecting. We also created the notion of an active "session", which we defined as a period of interaction with one of the systems that terminated after 10 minutes of inactivity. If an ASHA called into the voice-system multiple times within a 10-minute window, this was treated as one voice session. If, during that time, she also used the web system, it would be counted as one web session and one voice session. Before performing our analyses, we evaluated the Kolmogorov-Smirnov test to assess the normality of our data and found that it was statistically significant for all of our outcome metrics. As a result, we used non-parametric statistical methods for our analyses.

5.1 How did having access to feedback affect the number of clients an ASHA visited?

Our first research question aims to understand the impact of giving ASHAs access to feedback about their work on performance. For each ASHA in the control and treatment groups we calculated the average number of client visits per month that the ASHA made for the 12-month baseline period from June 2013 to June 2014 before the ASTA system was introduced and the average number of client visits per month for the 12-month intervention period from July 2014 to July 2015. Training was conducted during June 2015, so this month was omitted from analysis. We then calculated the difference between the average number of visits during the baseline and average number of visits during the intervention. This difference in means was our dependent variable that we analyzed based on treatment group.

A non-parametric Kruskal-Wallis test showed that there was a statistically significant difference between the *treatment* (ASTA) and *control* groups ($\chi^2 = 14.59$, $p = 0.0001$), with the average number of visits made by ASHAs changing from 8.76 to 8.04 visits per month in the *treatment* group, and 8.97 to 6.62 visits per month in the *control* group (see Figure 3). During the study period, the treatment group made 21.5% more visits than the control group.

These findings show that although the number of visits made by ASHAs in both groups actually decreased between the 12-month baseline period and the 12-month intervention period, the decline in performance was slower for the group that had access to the ASTA systems. The performance of ASHAs that had access to the ASTA system was consistently better than the performance of ASHAs in the control group. The performance drop of ASHAs in both groups during the study is likely attributed to supervision scale back in the ReMiND project during the deployment. Moreover, the 12-month baseline period represented the first year of the ReMiND project, and thus the decreased number of visits during our deployment may be explained by the novelty of the ReMiND application wearing off.

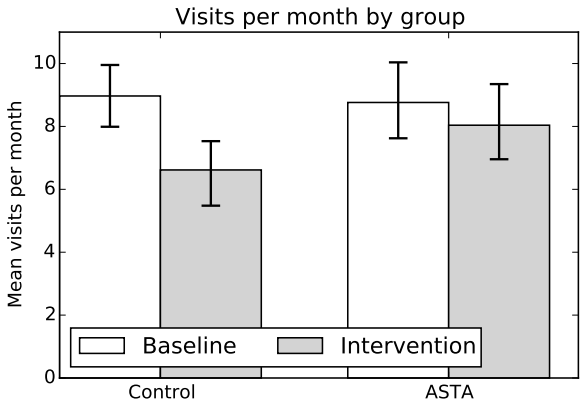

Figure 3: Mean number of visits done by ASHAs by group and time period. Error bars are the bootstrapped 95% confidence intervals.

Data obtained from qualitative interviews with ASHAs showed that the majority of ASHAs interviewed appreciated having the ability to see and/or hear data about their performance, especially the progress page. Not surprisingly, all ASHAs interviewed indicated that they felt very good when they saw either a high rank for themselves, or saw that they had completed a lot of their home visits. As one literate ASHA with a high school education explained:

> *"I like the comparison graph because it gives the details of other ASHAs and I can also determine the position of the ASHAs near me."*

One ASHA felt that the feedback was a clear indicator of how she was performing as an ASHA:

> *"...I am motivated. The amount of work we do tells about our success."*

Similarly, most of the ASHAs interviewed reported feeling disappointed when their rank was low or had dropped from prior months, explaining that they wanted to do better. Seeing their low rank highlighted that other ASHAs were doing more work than them. Three ASHAs mentioned that they felt frustrated when they were ranked low because they felt they could do nothing to improve their standing. When an ASHA has already visited all of her clients, the only way to improve her ranking is to register more pregnant women in her catchment area.

> *"When my ranking position was low then I felt badly... but I didn't have any new beneficiary that I could register..."*

Another ASHA also acknowledged the issue of not being able to register more women, but had a more positive reaction to it:

> *"I don't feel bad. We see only as much work as we did, so why feel bad? I have less work so I do less work, because my area is small."*

Another ASHA told us that the performance data also provided a direct reminder of the earnings that she obtained from her ASHA activities, so seeing poor performance made her sad since it meant she was not generating much income.

5.2 How did ASHA performance change over the 12 month deployment period?

In addition to understanding if there was an overall difference in performance between the control and intervention groups, we were also interested to assess how the performance of the two groups changed over time. To perform this analysis, we use a 2x2 factorial design with one between-subjects factor and one within-subjects factor. Our between-subjects factor was *treatment* with two levels: *ASTA* and *Control*. Our within-subjects factor was *month* with 12 levels: *July-June*. Since our data was non-normally distributed, our design warranted a non-parametric factorial analysis. For our continuous outcome measure (*number of visits*), we applied the Aligned Rank Transform (ART) [35] procedure, which aligns and ranks non-parametric data so a standard repeated measures ANOVA model can be used to perform the analysis. For each main effect or interaction, the ART procedure aligns the data such that only that main effect or interaction remains, and then ranks the aligned data. A standard repeated measures ANOVA model can then be used on the ranked data to measure the effect for which it was aligned. Unlike the conventional rank transform, the ART procedure is known to preserve the integrity of interaction effects and not inflate Type I errors. We used the ARTool program to align and rank our data [36, 16].

Figure 4 shows how ASHA performance changed over the 24 months of the baseline and intervention periods. Our analysis focuses on the 12-month study period in the shaded region. A repeated measures ANOVA conducted on the aligned and ranked data from the first six months of the treatment period shows that ASHAs in the intervention group made significantly more visits than those in the *control* group ($F_{1,140}$= 3.61, p=0.04). In addition, there was a significant *treatment*month* interaction, ($F_{5,700}$= 2.50, p=0.03). As can be seen in Figure 4, this significant interaction effect captures the increase in performance made by ASHAs in the intervention group in first few months of the study. However, when we performed the same repeated measures analysis for the entire 12 months of the study, the difference between the treatment and control groups decreased to borderline significance ($F_{1,140}$= 3.2, p=0.07), as did the *treatment*month* interaction ($F_{11,1540}$= 1.56, p=0.1). These results highlight what can be seen visually in Figure 4: the differences in performance between the ASTA and control groups decreased with time.

These findings demonstrate the importance of deploying ICT4D interventions for a relatively long period of time before drawing conclusions about their impact [27]. A light-touch performance improvement intervention like ASTA will naturally lose effectiveness over time. Studying the system over the course of 12-months provides insight into the duration of effectiveness and we believe that variation of the feedback mechanism may prolong this effectiveness.

We remain encouraged by the potential for a simple intervention like ASTA to positively impact ASHA performance for several months particularly because it is a relatively a low-cost intervention. Section 6.3 provides a more detailed discussion of the costs of deploying ASTA.

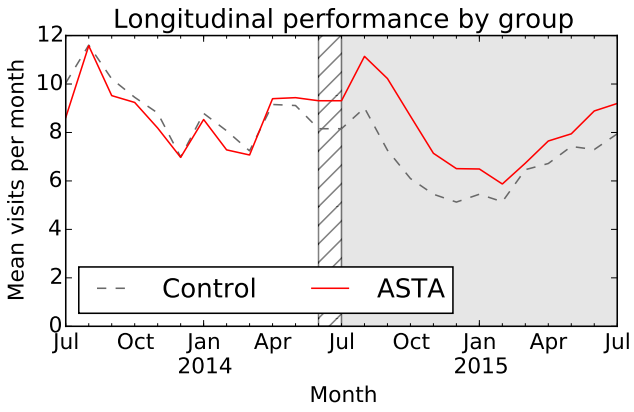

Figure 4: Mean number of visits done by study group and month. Hatched region is ASTA training. Shaded region is the intervention period.

5.3 Is there a correlation between ASTA usage and ASHA performance?

Our next research question aims to understand if ASHAs who accessed the ASTA system more frequently made more client visits than those who accessed it less frequently. To address this research question we analyzed data from only the 71 participants in the intervention group. We divided participants into equal thirds based on the total number of sessions with ASTA, labeling the third of participants who accessed the system the most as the high-usage group, the next third as the medium-usage group, and the final third as the low-usage group. Then, for each ASHA we used the difference in mean number of monthly client visits in the baseline and intervention periods. We analyzed the difference in means for each ASHA by usage group.

A Kruskal-Wallis test showed that there was a significant difference between the three groups ($\chi^2(2)$ = 8.22, p = 0.016), with the average number of monthly visits made by ASHAs changing from 11.3 to 12.0, 8.3 to 7.4, and 6.6 to 4.7 for the high-, medium-, and low-usage groups respectively. These data suggest that ASHAs who accessed the system most tended to be higher performing ASHAs. In addition, while the overall mean number of monthly visits for ASHAs using ASTA went from 8.76 to 8.04 , the ASHAs who used the ASTA most intensively held very steady in their performance (11.3 to 12.0).

When asked during the qualitative interviews about their opinions on how often the ASTA visualizations were updated, most ASHAs reported being comfortable with daily updates. Although some were eager to look at the system immediately after a home visit, others were less interested and would only notice the updates after a few days. Several ASHAs also noted that they did not look at the historical graph frequently because it did not change very often.

6. DISCUSSION

The results of our field study revealed a number of interesting benefits and challenges that the ASTA system provided. In this section we synthesize our results into a number of key takeaways.

6.1 The impact of the ASTA system on ASHAs

ASHAs generally responded positively to the performance feedback that they received through ASTA. For example, one ASHA explained a key aspect of the ASTA system that she appreciated:

> *"... I was motivated. When we didn't have ASTA we just worked according to our own motivation, but after ASTA we are able to know how much work we did and how much work is remaining..."*

ASHAs using ASTA performed significantly more monthly visits compared to the control group. A more detailed analysis revealed that the initial performance increase began to drop off after approximately six months of use. It is also important to note that, although the ASHAs using ASTA performed significantly better compared the control group, their performance still dropped over time. This is consistent with prior work that shows how, in the absence of quality supervision, CHW performance decreases over time [9].

It is also important to acknowledge that giving ASHAs access to comparative performance data runs the risk of potentially discouraging under-performing ASHAs while further encouraging high-performing ASHAs. In other words, the system is likely to amplify existing differences between low- and high-performing ASHAs, which is in line with Toyama's Law of Amplification [32]. Despite explicitly excluding evaluative feedback from the ASTA visualizations, ASHAs reported feeling bad when they found themselves ranked low. We believe that further investigation into ASHA motivations and the behavioral mechanisms activated by the ASTA system is a rich area for future research.

Finally, despite the participatory design process that we used to ensure that the visualizations were understandable, several ASHAs found the progress page to be confusing. Further investigation into this issue revealed that this was due to a number of small inconsistencies in the data that was used to populate the visualizations. For example, it is possible for the number of total registered clients in ASTA to be higher than the number of open clients in CommCare because ASTA also includes recently closed clients (i.e., those who have given birth). Similarly, there are several internal differences within ASTA. For example, the progress and history pages report the number of *unique* clients visited, but the calendar page reports the *total* number of client visits. Our interview data showed that these subtle differences led to confusion for some ASHAs, which in turn caused some frustration and distrust of the ASTA numbers. Future work will investigate how best to resolve these discrepancies without jeopardizing utility.

6.2 Benefits of multiple interaction modalities

One key way in which our research differs from many prior ICTD interventions is that, rather than choosing a single interaction modality, we instead provide ASHAs with access to *both* voice- and web-based feedback. Providing these two systems in parallel was well received by the ASHAs and our findings suggest that most ASHAs made use of both systems during the study, even when they preferred one system over the other. Feedback obtained during our qualitative interviews revealed a number of key advantages of having two parallel systems. For example, although the voice-based system was designed primarily to support low-literate ASHAs, it had the added benefit of supporting ASHAs who had difficulty seeing the visualizations on the small screen. In addition, giving ASHAs access to multiple channels provided redundancy, enabling access even if one system was unavailable, such as if an ASHA was experiencing limited connectivity or had exhausted their data bundle. These benefits were specifically described by several ASHAs in our study.

When asked about their preferences for one interaction mode over another, some ASHAs told us that they preferred the richness of the web-based system, others appreciated the concise messages provided by the voice-based system, while some illiterate ASHAs were only able to access the voice-based system. By providing multiple channels, we were able to cater to the needs of all the ASHAs.

6.3 Cost and sustainability

ASTA is a relatively low-cost intervention, with the primary costs being the voice line rental and usage, weekly SMS messages, web hosting, and the research assistant who provided technical support. Interestingly, many of these costs could be further reducted by transitioning the application to an Android production environment (and the study site—independent of our research—is currently transitioning ASHAs to Android devices). Android will enable the ASTA system to be built directly into the CommCare application, including rich native visualizations and voice-based feedback stitched together directly on the device. Importantly, incorporating ASTA directly into the CommCare application will also eliminate the primary responsibility of the research assistant: to ensure that the external system is accessible (i.e., resetting bookmarks and shortcuts). Peer data would still need to be pulled from the server, but this would be a small amount of data that would incur a low incremental cost. Instead, we believe it is more important to weigh the benefits of the ASTA system against the cost of increased cognitive load for ASHAs. Although much more difficult to quantify, it is necessary to be prudent when expanding the responsibilities of ASHAs so as not to overwhelm them.

Finally, although ASHA programs have been shown to be an effective way to reduce maternal and neonatal mortality in India, this can only be true if the ASHAs are doing their work. Our system resulted in a 21.5% increase in monthly visits performed by ASHAs. The most common way to produce a comparable increase in performance would be to increase in-person supervision, which is both labor intensive and expensive. We therefore consider ASTA to be a low-cost and effective way to improve ASHA performance.

6.4 Future work and Limitations

Our plans for future work fall under two main categories: building a better platform, and further investigating the social and behavioral mechanisms that may result in improved performance. As mentioned above, creating an Android version of ASTA will help to make the system more sustainable and scalable. In addition, we received a number of suggestions from ASHAs for how to improve the system. Several wanted the system to also include the newborn and young children that they track in the CommCare application, or enable them to collect specific information about what happened at each visit. Others expressed a wish that the voice-based system contain more of the content that is shown in the web-based graphs. We plan to incorporate these suggestions into future versions of the system.

In addition to improving the technology, there are also a

number of specific research questions that warrant further investigation. For example, we plan to further explore additional mechanisms for performance improvement, such as goal-setting, leader boards, or providing evaluative feedback. The novelty effect that we observed also warrants further attention. Specifically, we plan to investigate ways in which we might increase the duration of the performance gains that result from deploying the intervention. We belive that periodically releasing new gamification mechanisms or visualizations may help to sustain performance levels, or possibly rotating through a set of different feedback mechanisms or visualizations on a regular basis.

Our research also has several limitations. For example, the performance data that we used as the key metric in ASTA was derived from self-reported CommCare visits and may not be entirely accurate. Supervisory staff from ReMiND carefully reviewed ASHA work, which gives us anecdotal confidence in the accuracy of the data. Furthermore, an audit of ASHA visits is currently ongoing and will help to assess the reliability of the visit data.

Finally, it is important to note that the results of this study exist within the context of the ReMiND project, which involves a CommCare deployment and an increased level of supervision and support for the ASHAs. In mobile health interventions, strong training and support are believed to be essential for success. Further work is required to understand and test the results in different contexts. We are careful not to claim generalizability of the effectiveness of ASTA too broadly outside of strong existing supervisory structures.

7. CONCLUSION

ASHAs are increasingly important members of the public health system and many organizations are deploying mobile health tools in an effort to support ASHAs in the field. This paper presents the ASHA Self-Tracking Application (ASTA), a tool developed to test the hypothesis that closing the feedback loop will increase ASHA performance. The system works by allowing ASHAs to access feedback about their performance on demand. Our 12-month deployment of ASTA showed that ASHAs completed 21.5% more monthly visits on average compared to a control group. Moreover, higher ASHA performance was correlated with increased usage of the ASTA system. However, the performance improvement was front-loaded, with the impact of the system decreasing toward the end of the study period. Taken together, our findings provide promising evidence that studying and incorporating tools like ASTA could be cost effective and impactful for ASHA programs. We view this paper as a step in a larger research agenda focused on low-cost, easily deployable performance improvement tools for community health workers.

8. ACKNOWLEDGMENTS

We thank all of the ASHAs for their time, patience, and for the important work that they do; Vatsalya and CRS for being strong collaborators in this work; and the research assistants who contributed to this project. Finally, we thank the reviewers for their valuable feedback and suggestions. This work was supported by the Massachusetts General Hospital Consortium for Affordable Medical Technologies (CAMTech) and NSF Research Grant No. IIS-1111433.

9. REFERENCES

[1] Uttar Pradesh State Profile. http://nrhm.gov.in/nrhm-in-state/state-wise-information/uttar-pradesh.html.

[2] Census of India. http://censusindia.gov.in/2011-prov-results/paper2/data_files/UP/7-pop-12-22.pdf, 2011.

[3] Baseline Study Summary: ReMiND. Technical report, Catholic Relief Services, 2013.

[4] S. , J. Walley, E. Katabira, S. Muchuro, H. Balidawa, E. Namagala, and E. Ikoona. Using mobile phones to improve clinic attendance amongst an antiretroviral treatment cohort in rural Uganda: a crosssectional and prospective study. *AIDS and behavior*, 14(6):1347–1352, 2010.

[5] A. H. Baqui, S. El-Arifeen, G. L. Darmstadt, S. Ahmed, E. K. Williams, H. R. Seraji, I. Mannan, S. M. Rahman, R. Shah, S. K. Saha, et al. Effect of community-based newborn-care intervention package implemented through two service-delivery strategies in Sylhet district, Bangladesh: a cluster-randomised controlled trial. *The Lancet*, 371(9628):1936–1944, 2008.

[6] M. Berg, J. Wariero, and V. Modi. *Every child counts: The use of SMS in Kenya to support the community based management of acute malnutrition and malaria in children under five*. Columbia University, 2009.

[7] E. Borkum, A. Sivasankaran, S. Sridharan, D. Rotz, S. Sethi, M. Manoranjini, L. Ramakrishnan, and A. Rangarajan. Evaluation of the Information and Communication Technology (ICT) Continuum of Care Services (CCS) Intervention in Bihar. Technical report, Mathematica Policy Research, May 2015.

[8] C. Bourne, V. Knight, R. Guy, H. Wand, H. Lu, and A. McNulty. Short message service reminder intervention doubles sexually transmitted infection/HIV retesting rates among men who have sex with men. *Sexually transmitted infections*, 87(3):229–231, 2011.

[9] B. DeRenzi, L. Findlater, J. Payne, B. Birnbaum, J. Mangilima, T. Parikh, G. Borriello, and N. Lesh. Improving Community Health Worker Performance Through Automated SMS. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*, ICTD '12, pages 25–34, New York, NY, USA, 2012. ACM.

[10] B. DeRenzi, N. Lesh, T. Parikh, C. Sims, W. Maokla, M. Chemba, Y. Hamisi, M. Mitchell, and G. Borriello. e-IMCI: Improving pediatric health care in low-income countries. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 753–762. ACM, 2008.

[11] B. DeRenzi, C. Sims, J. Jackson, G. Borriello, and N. Lesh. A framework for case-based community health information systems. In *Global Humanitarian Technology Conference (GHTC), 2011 IEEE*, pages 377–382. IEEE, 2011.

[12] J. F. Florez-Arango, M. S. Iyengar, K. Dunn, and J. Zhang. Performance factors of mobile rich media job aids for community health workers. *Journal of the American Medical Informatics Association*, 18(2):131–137, 2011.

[13] B. Fogg and E. Allen. 10 uses of texting to improve health. In *Proceedings of the 4th International Conference on Persuasive Technology*, Persuasive '09, pages 38:1–38:6, New York, NY, USA, 2009. ACM.

[14] M. S. Iyengar, J. F. Florez-Arango, and C. A. Garcia. GuideView: a system for developing structured, multimodal, multi-platform persuasive applications. In *Proceedings of the 4th International Conference on Persuasive Technology*, page 31. ACM, 2009.

[15] N. Jain, N. Srivastava, A. Khan, N. Dhar, S. Manon, V. Adhish, and D. Nandan. Assessment of functioning of ASHA under NRHM in Uttar Pradesh. *Health and Population: Perspectives and Issues*, 31(2):132–140, 2008.

[16] M. Kay. Cran - package artool. https://cran.r-project.org/web/packages/ARTool/, 2015. [Online; accessed 12-November-2015].

[17] G. Kidane and R. H. Morrow. Teaching mothers to provide home treatment of malaria in Tigray, Ethiopia: a randomised trial. *The Lancet*, 356(9229):550–555, 2000.

[18] P. Klasnja and W. Pratt. Healthcare in the pocket: mapping the space of mobile phone health interventions. *Journal of biomedical informatics*, 45(1):184–198, 2012.

[19] V. Kumar, S. Mohanty, A. Kumar, R. P. Misra, M. Santosham, S. Awasthi, A. H. Baqui, P. Singh, V. Singh, R. C. Ahuja, et al. Effect of community-based behaviour change management on neonatal mortality in Shivgarh, Uttar Pradesh, India: a cluster-randomised controlled trial. *The Lancet*, 372(9644):1151–1162, 2008.

[20] U. Lehmann, D. Sanders, et al. Community health workers: What do we know about them? *World Health Organization*, 2:1–42, 2007.

[21] N. Mahmud, J. Rodriguez, and J. Nesbit. A Text Message-based Intervention to Bridge the Healthcare Communication Gap in the Rural Developing World. *Technol. Health Care*, 18(2):137–144, Apr. 2010.

[22] I. Medhi, S. Patnaik, E. Brunskill, S. N. Gautama, W. Thies, and K. Toyama. Designing Mobile Interfaces for Novice and Low-literacy Users. *ACM Trans. Comput.-Hum. Interact.*, 18(1):2:1–2:28, May 2011.

[23] T. Oluoch, X. Santas, D. Kwaro, M. Were, P. Biondich, C. Bailey, A. Abu-Hanna, and N. de Keizer. The effect of electronic medical record-based clinical decision support on HIV care in resource-constrained settings: A systematic review. *International journal of medical informatics*, 81(10):e83–e92, 2012.

[24] N. Patel, K. Shah, K. Savani, S. R. Klemmer, P. Dave, and T. S. Parikh. Power to the Peers: Authority of Source Effects for a Voice-based Agricultural Information Service in Rural India. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*, ICTD '12, pages 169–178, New York, NY, USA, 2012. ACM.

[25] S. Patnaik, E. Brunskill, and W. Thies. Evaluating the Accuracy of Data Collection on Mobile Phones: A Study of Forms, SMS, and Voice. In *Proceedings of the 3rd International Conference on Information and Communication Technologies and Development*, ICTD'09, pages 74–84, Piscataway, NJ, USA, 2009. IEEE Press.

[26] D. Ramachandran, J. Canny, P. D. Das, and E. Cutrell. Mobile-izing Health Workers in Rural India. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 1889–1898, New York, NY, USA, 2010. ACM.

[27] P. M. Rothwell. Factors that can affect the external validity of randomised controlled trials. *PLoS Clin Trials*, 1(1):e9, 2006.

[28] A. Rowe, D. Desavigny, C. Lanata, and C. Victora. How can we achieve and maintain high-quality performance of health workers in low-resource settings? *The Lancet*, 366(9490):1026–1035, 2005.

[29] J. Sherwani, N. Ali, S. Mirza, A. Fatma, Y. Memon, M. Karim, R. Tongia, and R. Rosenfeld. Healthline: Speech-based access to health information by low-literate users. In *Information and Communication Technologies and Development, 2007. ICTD 2007. International Conference on*, pages 1–9. IEEE, 2007.

[30] J. Stekelenburg, S. Kyanamina, and I. Wolffers. Poor performance of community health workers in Kalabo District, Zambia. *Health policy (Amsterdam, Netherlands*, 65(2):109–118, 2003.

[31] D. Thea and S. Qazi. Neonatal mortality–4 million reasons for progress. *The Lancet*, 371(9628):1893–1895, 2008.

[32] K. Toyama. *Geek heresy: Rescuing social change from the cult of technology*. PublicAffairs, 2015.

[33] A. Vashistha, E. Cutrell, G. Borriello, and W. Thies. Sangeet Swara: A Community-Moderated Voice Forum in Rural India. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 417–426, New York, NY, USA, 2015. ACM.

[34] P. Winch, K. Gilroy, C. Wolfheim, E. Starbuck, M. Young, L. Walker, and R. Black. Intervention models for the management of children with signs of pneumonia or malaria by community health workers. *Health Policy and Planning*, 20(4):199–212, 2005.

[35] J. O. Wobbrock, L. Findlater, D. Gergle, and J. J. Higgins. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 143–146, New York, NY, USA, 2011. ACM.

[36] J. O. Wobbrock, L. Findlater, D. Gergle, J. J. Higgins, and M. Kay. Artool. https://depts.washington.edu/aimgroup/proj/art/, 2015. [Online; accessed 12-November-2015].

[37] S. Yadav. A study of treatment seeking behaviour for malaria and its management in febrile children in rural part of desert, Rajasthan, India. *Journal of vector borne diseases*, 47(4):235–242, 2010.

[38] D. Zurovac, R. K. Sudoi, W. S. Akhwale, M. Ndiritu, D. H. Hamer, A. K. Rowe, and R. W. Snow. The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial. *The Lancet*, 378(9793):795–803, 2011.